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ALEGRA Simulations of Radiatively-Driven Supersonic-Jet Experiments Scaled to Z / ZBL Conditions

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Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy under contract DE-AC04-94AL85000.

We are using ALEGRA to simulate radiation-driven jet experiments on both NOVA and Z.

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- ALEGRA is being validated by comparison with NOVA test results and with other calculations.
- Similar experiments on Z offer flexibility and the potential for physical scale-up by an order of magnitude.
- The Z-Beamlet backlighter can be used to study the generation and dynamic evolution of the jets on scaled-up configurations.

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The NOVA experiments used radiation from a short-pulse, high-power, laser-driven hohlraum.

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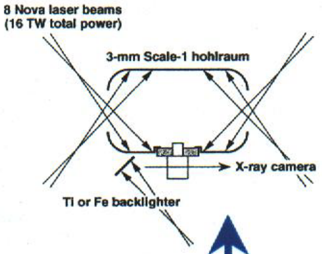
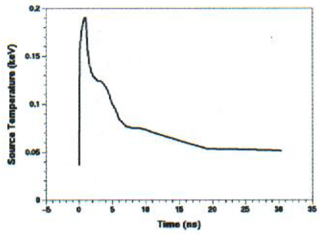
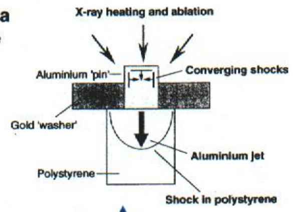


The experiment used a laser-driven NOVA hohlraum to expose the sample to a short high-intensity radiation load. The sample response was observed with an x-ray backlighter.

The radiation drive was a blackbody temperature history peaking at ~190 eV with a FWHM pulse width of ~5 ns.





The target configuration consisted of a 150-μm-long aluminum "pin" in a 50-μm-thick gold "washer," which was backed with a 380-μm-diameter polystyrene block.

The configuration used for the ALEGRA calculations employed an Al "pin" mounted in an Au "washer."

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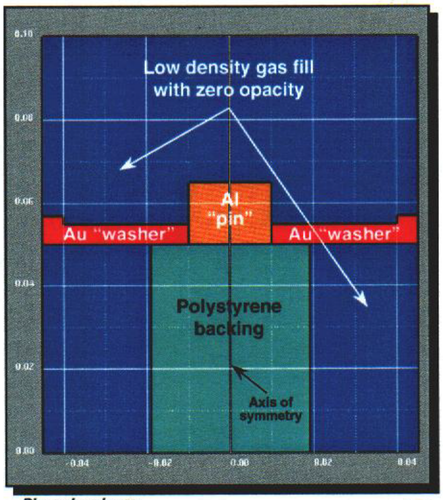
- For the NOVA problem, the thickness of the aluminum "pin" was 150 μm, the gold washer thickness was 50 μm, and the polystyrene backing had a diameter of 380 μm.
- We used a 2-D cylindrical Eulerian mesh with: 1) 4,500 elements (10-μm resolution); and 18,000 elements (5-μm resolution, respectively).
- The radiation, incident from the top, was treated with single-group, SN_1 radiation transport, with radiation pressure disabled.



Dimensions in cm

For NOVA, fine resolution calculations show more detail and slightly faster on-axis jet motion.

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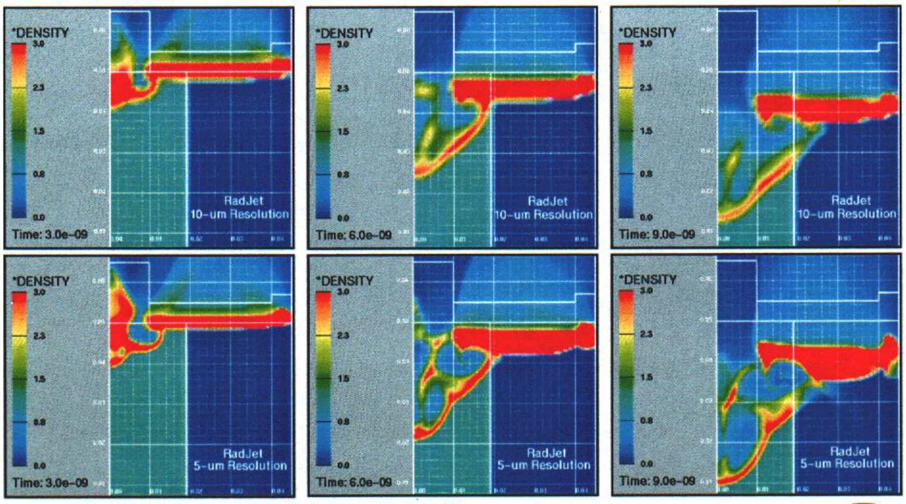
Coarse resolution calculation →



Fine resolution calculation →

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SPECT3D produces simulations of detector images from ALEGRA rad/hydro output.

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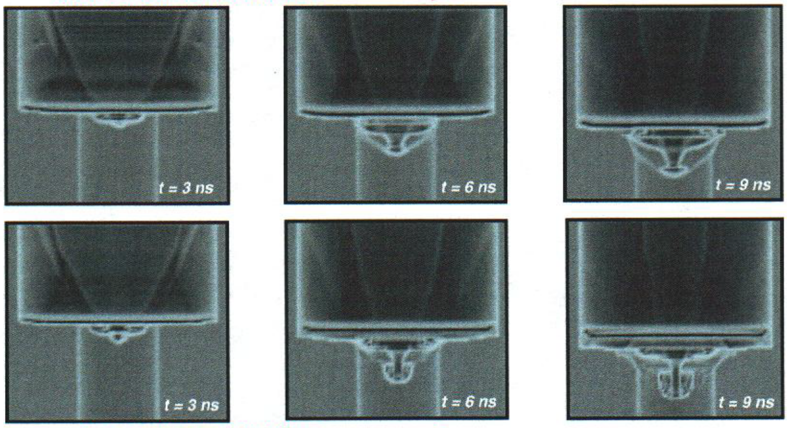
Coarse resolution calculation →



Fine resolution calculation →

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For this configuration the ALEGRA results are consistent with other codes and the experiment.

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Spatial characterization of aluminum jet (Revised configuration – coarse mesh):

[Axial position of leading edge (μm)]

Code	ALEGRA *(Eulerian)*	PETRA *(Eulerian)*	CALE *(ALE)*	RAGE *(AMR)*	Experiment *(Estimated)*
Time = 6 ns	265	245	300	280	~260
Time = 9 ns	380	345	405	380	300+
Time = 12 ns	460	–	–	–	–

- ***At a computational time of 6 ns, ALEGRA predicts the on-axis jet location within about 2% of the estimated experimental result; this result is also consistent with the other computational efforts.***
- ***At a time of 9 ns the predicted axial location of the jet is somewhat over 20% greater than the estimated experimental measurement; but as with the earlier time, it agrees very closely with the average of the other code results.***

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We are now studying the scaling of these RadJet experiments from NOVA to Z.

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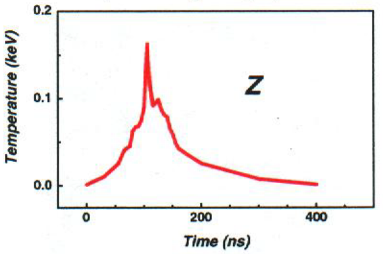

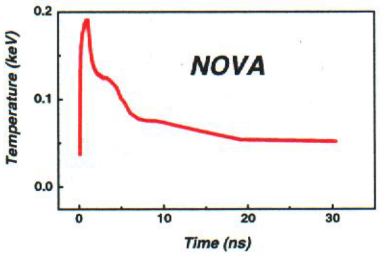

Typical Source Characteristics

Peak temperature:

NOVA	~190 eV
Z	~162 eV

FWHM pulse width:

NOVA	~5 ns
Z	~50 ns

Peak power:

$P_{PK}(Z)/P_{PK}(NOVA) \approx 1/2$

Total energy:

$E_{TOT}(Z)/E_{TOT}(NOVA) \approx 3$

- ***Similar mechanical behavior should be obtained by scaling the physical dimensions by about a factor of ten.***
- ***However, the radiation transport will not scale in a similar fashion.***
- ***Source for Z can be modified.***

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There are several points that should be noted with regard to the calculations.

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- The quoted half-max pulse widths are only approximate, but lead to about a factor of ten difference in characteristic response times.
- In these calculations the physical dimensions are scaled by exactly a factor of ten for the two cases.
- Because the radiation transport phenomena (*e.g.,* opacities) do not scale in the same manner as the hydrodynamic behavior, the total response will not be directly homologous.
- The calculations were run with ALEGRA, using 10-µm resolution for the NOVA case and 100-µm resolution for the Z configuration.
- Because of the initial slow rise for the radiation drive from Z, the times cannot be shifted in a directly proportional fashion; the comparison plots were chosen for similar stages in the evolution of the response.

The RadJet problem at very early times, with the shock part way through the "pin" . . .

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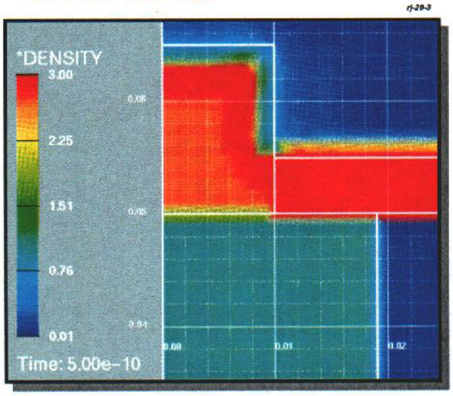
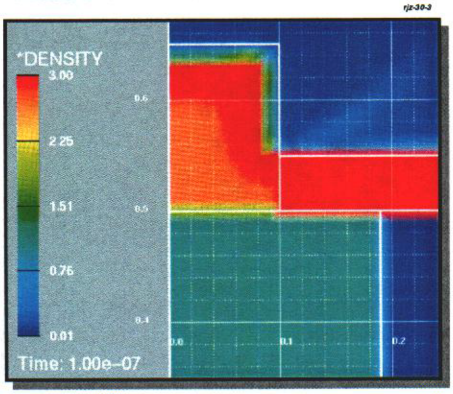
RadJet / NOVA:



RadJet / Z:



Dimensions in cm

The RadJet problem at early times, at about the time of shock breakout . . .

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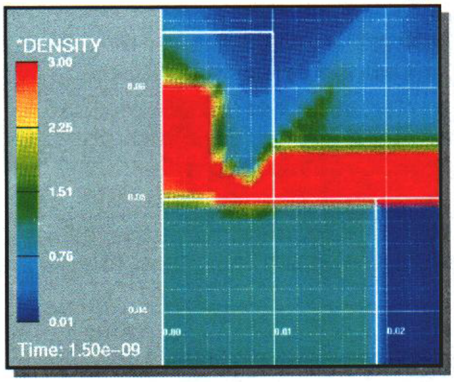
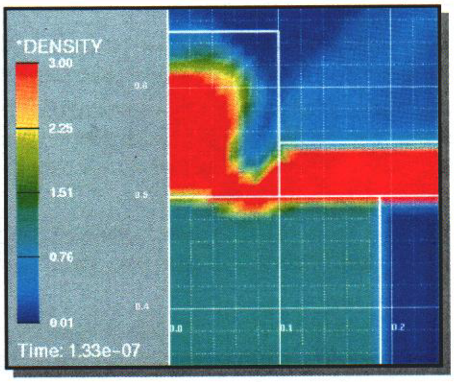
RadJet / NOVA:



RadJet / Z:



Dimensions in cm

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The RadJet problem at medium time, after the "jet" is relatively well formed . . .

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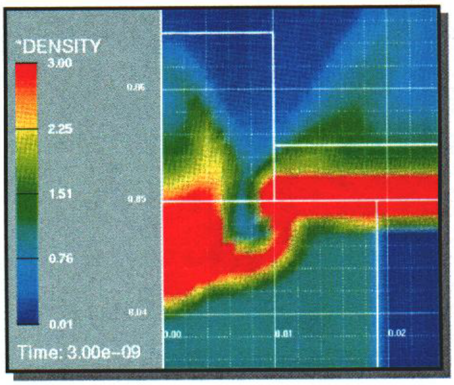
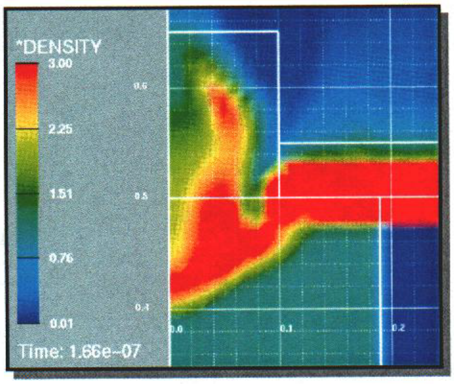
RadJet / NOVA:



RadJet / Z:



Dimensions in cm

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At later times the problems are still similar, and the jet is well into the polystyrene backing.

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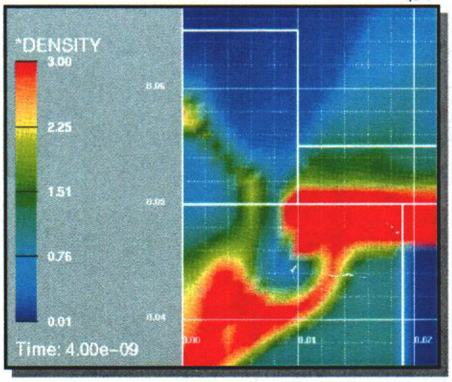
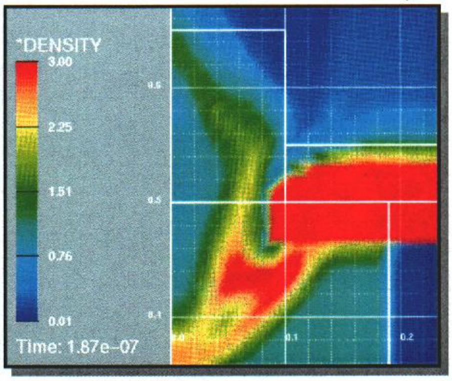
RadJet / NOVA:



RadJet / Z:



Dimensions in cm

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By late times, the differences due to lack of radiation "scaling" are considerably more evident.

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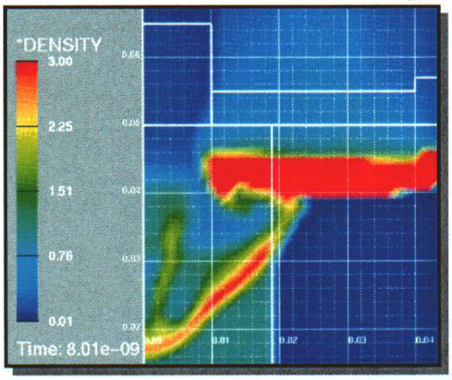
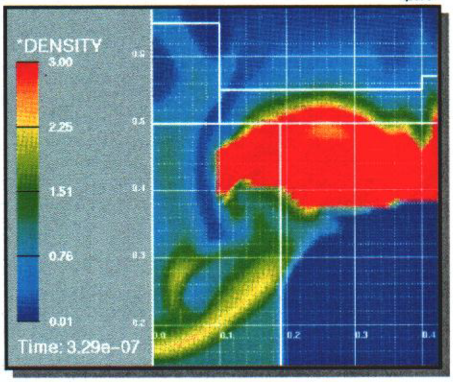
RadJet / NOVA:



RadJet / Z:



Dimensions in cm

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Temperatures and pressures show much larger differences than the densities.

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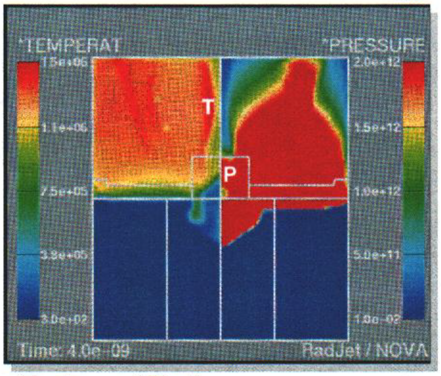
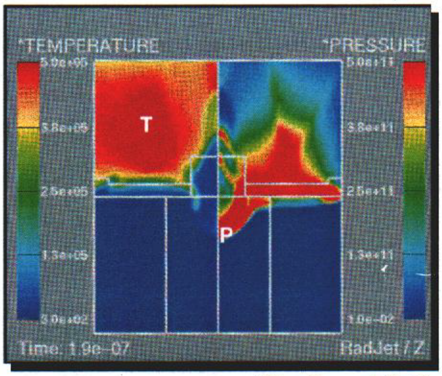
RadJet / NOVA:



'T' -- $T_{max} \cong 130$ eV
'P' -- $P_{max} \cong 30$ Mb

RadJet / Z:



'T' -- $T_{max} \cong 50$ eV
'P' -- $P_{max} \cong 3$ Mb

At much later times there are significant differences, but many qualitative features are similar.

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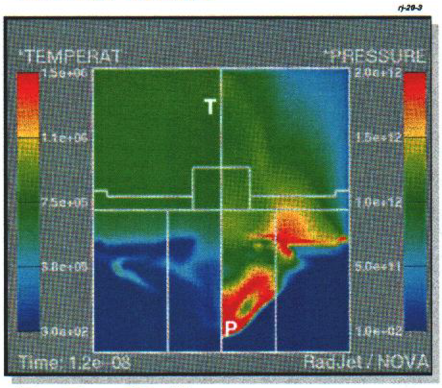
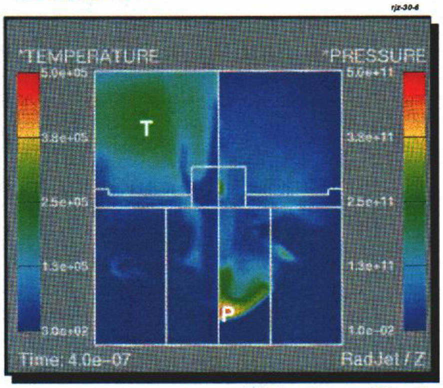
RadJet / NOVA:



'T' -- $T_{max} \cong 70$ eV
'P' -- $P_{max} \cong 4$ Mb

RadJet / Z:



'T' -- $T_{max} \cong 20$ eV
'P' -- $P_{max} \cong 0.5$ Mb

The Z Backlighter is scheduled to begin operation on Z in early 2001.

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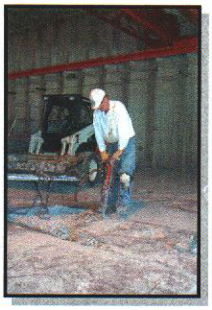
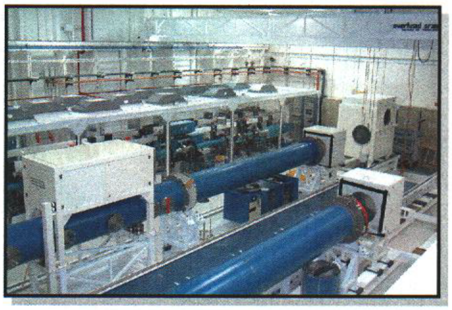
- Construction of the ZBL building began in March 1999.
- Construction of the ZBL building was completed in October 1999.
- The front end activation was completed in February 2000.



March 1999



March 2000

A versatile x-ray backlighter will revolutionize high energy density physics experiments on Z.

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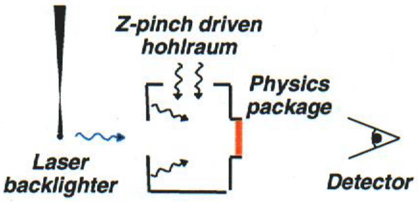
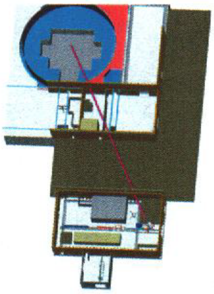


Measurements possible with a backlighter:

- Material T_e and n_e
- Magnetic Rayleigh-Taylor growth rate
- Absorption spectrum
- Capsule implosion symmetry
- Material interface motion
- Particle velocity and shock density
- Instability mix region

2 TW laser backlighter on Z --



- Capabilities include both point projection and area backlighting.
- We will have spatial resolution of 25 μm at 9 keV x-ray probe energy.

We are using SPECT3D to visualize the use of the Z-Beamlet Backlighter (ZBL) on these experiments.

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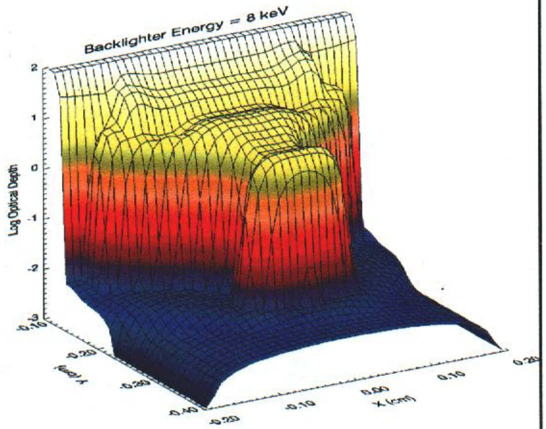
- The amplitude of each cell represents the optical depth through the jet as a function of axial position (Y) and offset from the axis (X).
- For this example the backlighter energy was chosen as 8 keV.
- This plot is taken from the 100-μm resolution RadJet / Z calculation at a time of 330 ns.
- Each cell represents one zone of the ALEGRA rad/hydro calculation.



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Lower ZBL photon energies have better conversion efficiencies, but cannot "see" through jet.

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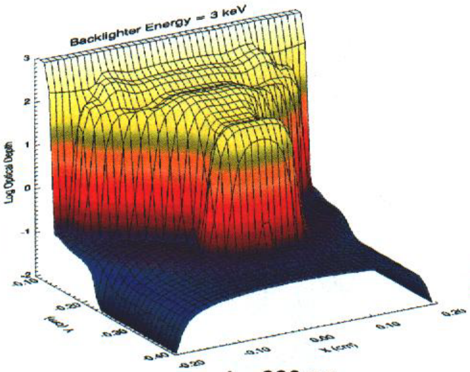
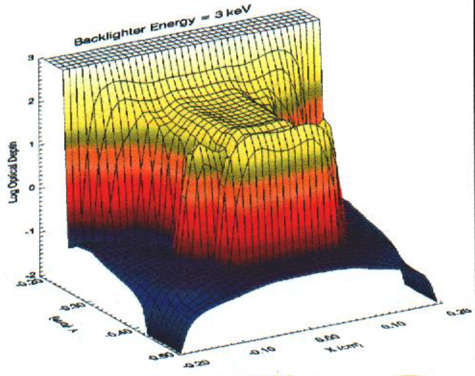


t = 330 ns

Backlighter photon energy:
hν = 3 keV



t = 528 ns

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Overall, ZBL performance depends on photon energy, conversion efficiency, and other issues.

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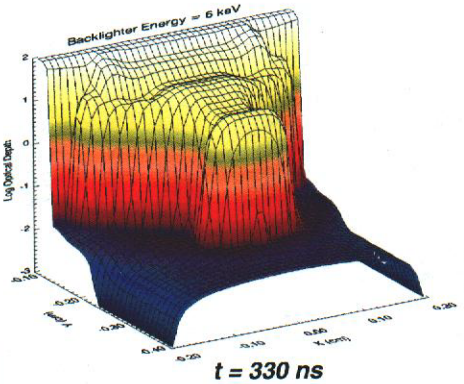
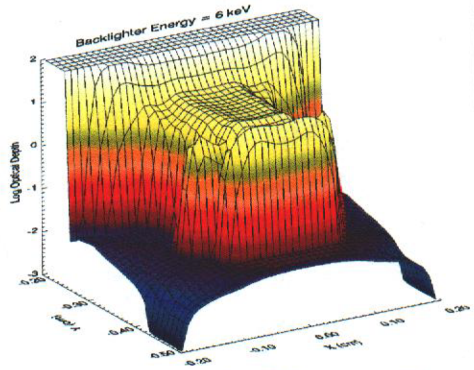
Backlighter photon energy:
$h\nu$ = 6 keV



t = 330 ns



t = 528 ns

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At late times and 10 keV, we get optical depths of order unity, which implies experiment is feasible.

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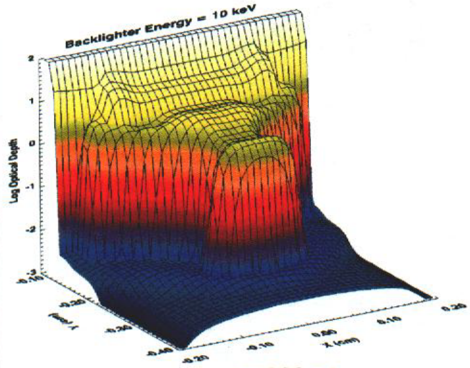
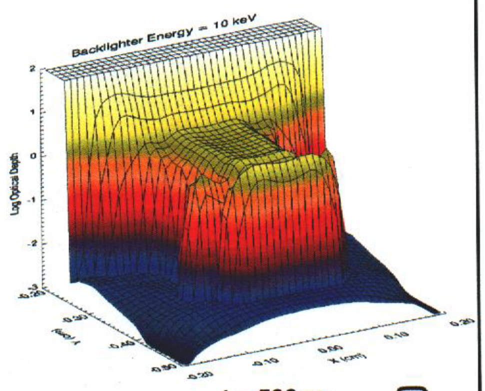
Backlighter photon energy:
$h\nu$ = 10 keV



t = 330 ns



t = 528 ns

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Simulations of detector output from the scaled-up Z runs show all major features.

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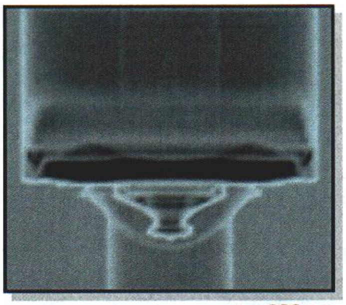
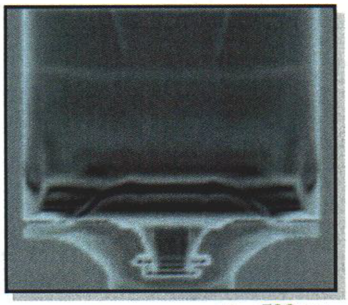
- These images were generated with $h\nu = 10$ keV.
- Features evident in the radiographs include the polystyrene backing block, the shock wave in the polystyrene, and details of the aluminum jet in the plastic.
- Details of the blowoff moving back into the hohlraum are also evident, but would not be recorded in the experimental radiograph.



t = 330 ns



t = 528 ns

We have studied the generation and evolution of radiation-driven jets on both NOVA and Z.

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- The NOVA experiments, in conjunction with the other calculations, have provided validation for the ALEGRA modeling and analyses.
- In comparison with the results from NOVA, physical scaling-up of the configuration and using the Z-pinch machine produces similar, although not identical, phenomenology.
- Using the ZBL backlighter for diagnostic measurements appears to be feasible for the scaled-up configuration.
  > At late times and for high photon energies, optical depths are of order unity.
- Next steps and other possibilities:
  > Use finer zoning for ALEGRA calculations;
  > Use more realistic and representative ZBL spectra;
  > Modify Z source to obtain different conditions (*e.g.*, higher temperatures via dynamic hohlraum, multiple and/or colliding jets);
  > Examine different configurations of interest, or other degrees of physical scale-up.